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REV. J. L. ZABRISKIE,

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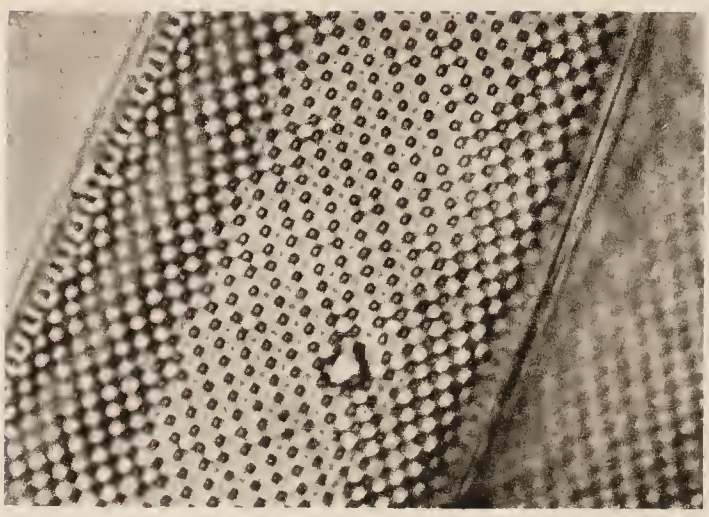

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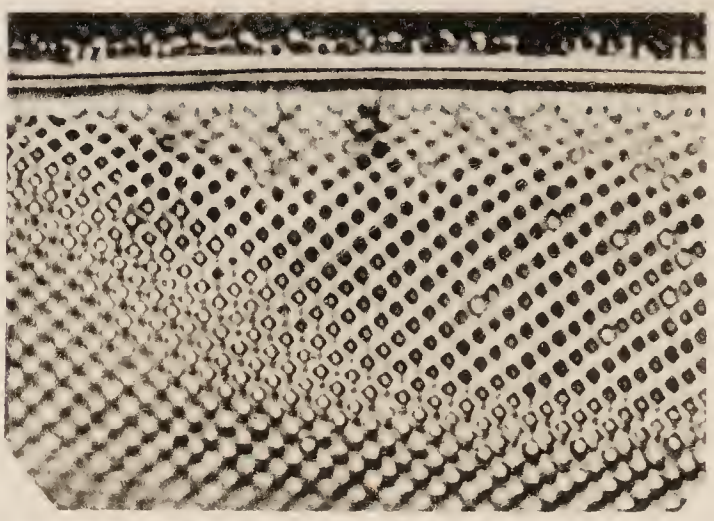

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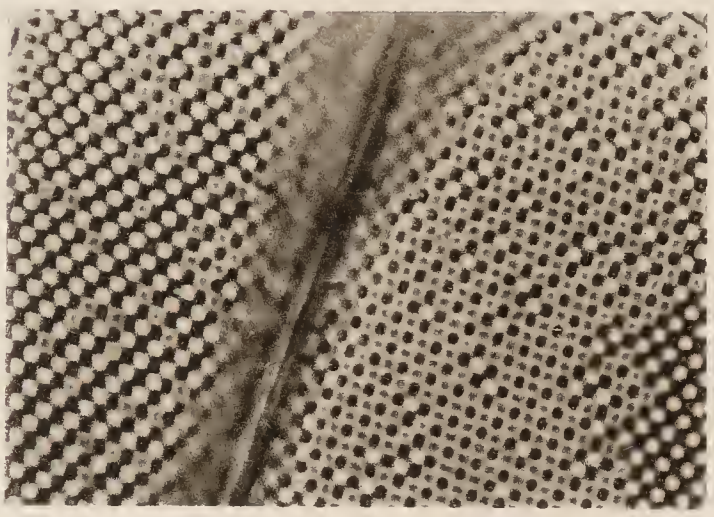

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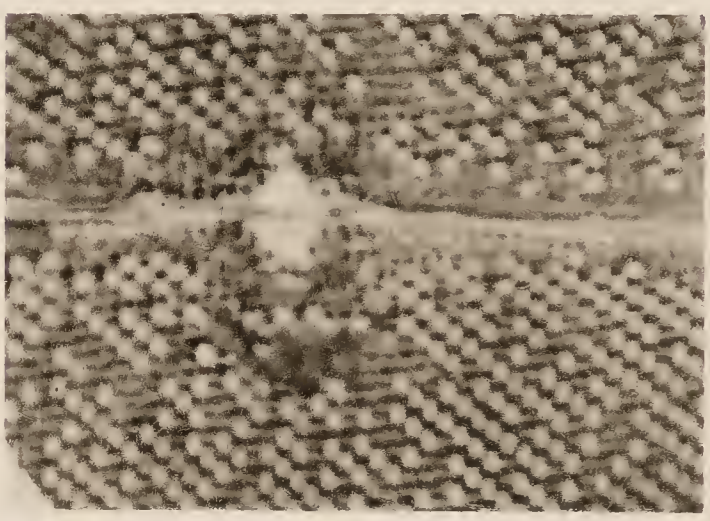

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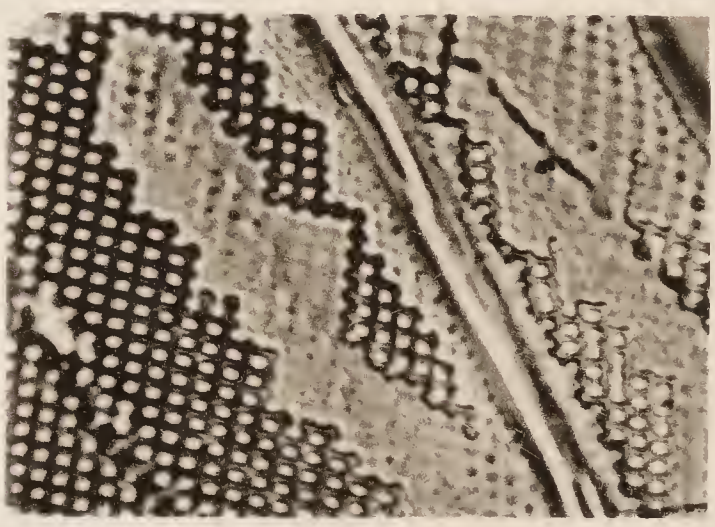

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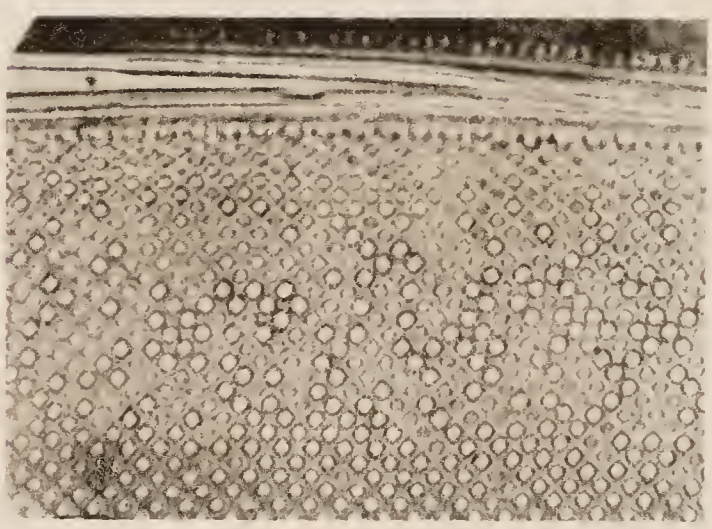

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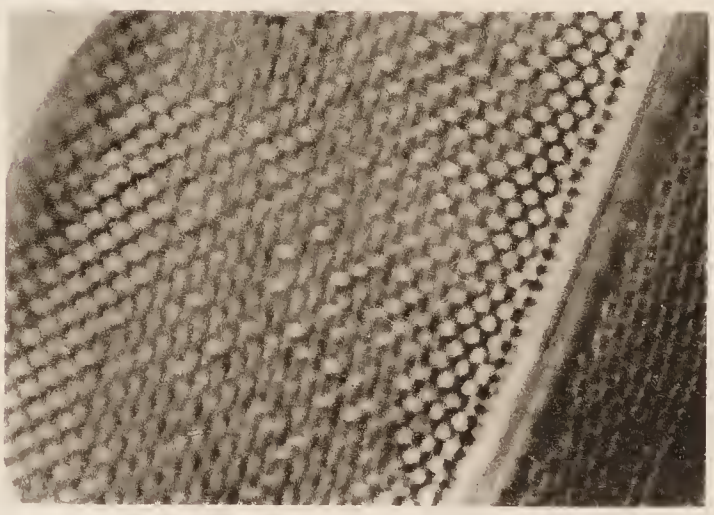

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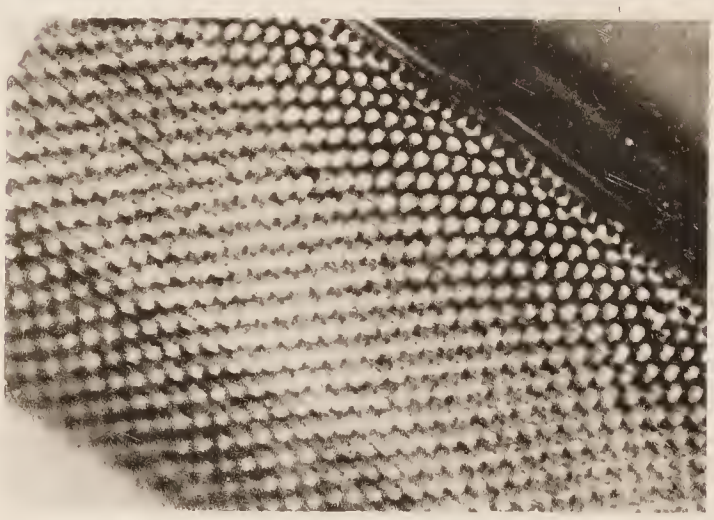

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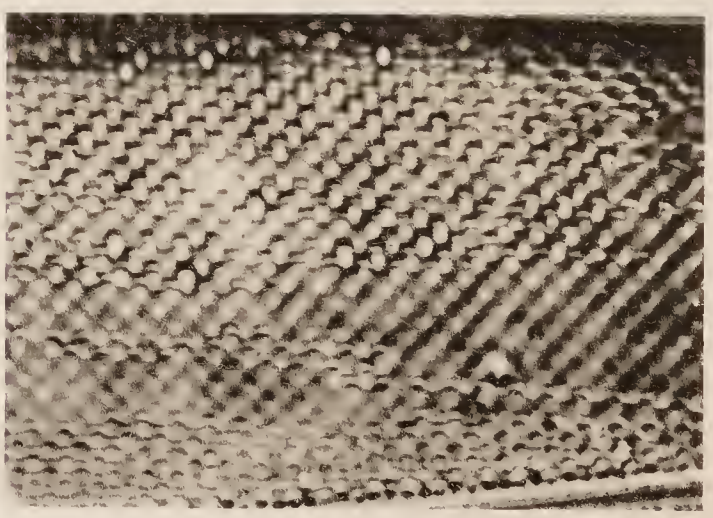

T. F. SMITH ON THE STRUCTURE
OF THE
PLEUROSIGMA VALVE.

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ON THE STRUCTURE OF THE PLEUROSIGMA VALVE.

BY T. F. SMITH, F.R.M.S.

(*Read January 2d*, 1891.)

On September the 28th, 1888, I had the honor of reading before the Quekett Club a paper bearing the above title, in which I attempted to prove that the supposed single plate of silex forming the pleurosigma valve was, in reality, built up of two or three layers of structure.

That this idea of mine was not a new one I subsequently discovered and admitted in a paper on the same subject, read by me before the Royal Microscopical Society, in which I quoted the remarks of Herr Grunow and Mr. Kitton on the subject. I also have taken the opportunity in this paper of bearing testimony to the labors of Dr. Jacob D. Cox in working out the structure of the diatom-shell; who, although he makes no positive statement on the pleurosigma valve, says that certain appearances are "not inconsistent with a double structure."

Incidentally I may say that after arriving at a certain stage of my work I searched through the collections of photographs of diatom-structure belonging to the Royal Microscopical Society, and found Dr. Cox's prints of *P. angulatum* to be the only ones giving a correct rendering of one of the layers—the one shown in my slides Nos. 35, 36, and 37 of that diatom.

The reason is very simple: This layer can only be distinguished from the one on the other side of the valve by the use of a large cone of light; and having so distinguished it, I think America can

claim in Dr. Cox the first worker in photomicrography under those new, and the only true, conditions.

But, while making no claims now to be the first to originate this idea of a compound structure in the finer forms of diatoms, I think I may claim to have been the first to attempt to photograph the different layers; not from possessing any superior powers of observation, but because the work was only possible after the advent of the new apochromatic lenses from Germany.

When we consider the difference between the actinic and the visual foci in the best lenses of the ordinary achromatic correction when used photographically, and also the infinitesimal distances which must separate the different layers in the valves of the minute forms of diatoms, it will be seen at once how utterly impossible it would be to make any allowance fine enough to bring the particular layer aimed at sharp in focus on the negative. The reduction, however, of the secondary spectrum in the apochromatics entirely obliterates this difference, and what is seen sharp on the focussing screen may be depended upon to be sharp in the negative, given correct exposure and development.

This capacity of standing more light was pointed out from the first by Mr. E. M. Nelson, but has not received the attention it deserves; and the neglect of this point has stultified the efforts of many microscopists, both here and on the Continent, to get more out of the new glasses than the old objectives. Unfortunately, the most flagrant examples of "how not to do it" come from the very workshop which produces the glasses, and Dr. Roderick Zeiss' celebrated print of *P. angulatum* shows how an oil-immersion apo: of 1.3 N. A. may be made to perform no better than a good dry $\frac{1}{4}$-inch.

The conclusion arrived at in my first paper is that the valve of *P. formosum*—as being the one most easily studied from its coarse structure—consists of three layers, figured as Nos. 1, 2, and 5 in the plate belonging to that paper.

The figures may still be taken as correct representations of the layers, but I am afraid this is the only part not rendered obsolete by subsequent observations by myself, and most of the theories proposed there must be thrust aside as crude deductions from imperfect observations. The figures of *P. formosum* may stand, but that given of the middle layer is not the middle layer at all

in the sense of its occupying the centre of the section of the valve. To understand its position it must be remembered that in section the valve is V-shaped (Fig. 1); No. 1 being the inner, No 3 the extreme outer side of the valve, and No. 2 immediately under No. 3, and optically, but not structurally, a part of it. When I say optically a part, I mean that had I not seen them separated I should never have ventured to declare them different layers. Nos. 1 and 2 are comparatively robust in structure, while No. 3 is exceedingly fragile and often seen lying in strips on the face of the valve; and it is from the fact that under these circumstances No. 2 is still found sound I have been able to differentiate the two. This difference of curve between the two sides of the valve is seen to run through all the species of *Pleurosigma*, although in none of them are they so pronounced in character as in *P. formosum*. This difference always corresponds with a difference of

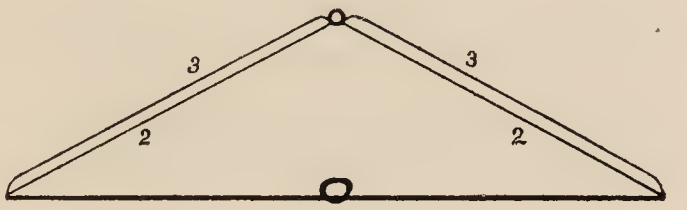

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FIG. 1.

appearance, and although I do not believe the variation, structurally, between the two sides of some of them is much, it must be enough to account for the difference.

The first four of the series of lantern slides sent to illustrate this paper are numbered 1, 2, 3, and 4, and represent the three layers of the valve of *P. formosum;* Nos. 1 and 2 being taken from the inner side and showing it to be nearly flat in section. The structure of this layer seems to be a square grating set lengthways on the valve, and its peculiarity is that on the same plane the focal images are formed in the alternate squares of the grating only, giving the usual appearance of the diagonal markings. On the outer focus the alternate holes are red, the interspaces white, as in slide No. 12; but on focussing inward the white interspaces turn into green "beads," and the outer red interspaces become white. This red and green is not merely a negative and positive image of the same structure, but formed in entirely

different positions (Fig. 2), the "×" marking the red, and the "o" the green. Taking note of the difference of the colors in the alternate holes of a grating may seem trivial to a biologist marking out, say, the life history of some obscure organism, but in reality it points out a valuable quality belonging to an apochromatic lens only and helping to call attention, in all branches of microscopic research, to points which else might escape attention. I say this advisedly, having tested some of the finest glasses of our English makes, but not apochromatics, on this object; and although the two sets were shown in their proper positions, they were both of the same color, and thus the different positions likely to escape notice. I have not yet been able to discover the cause of the two sets of images in this layer. There is no difficulty about the outer red ones being simply the alternate holes of the grating; but I can find no cause for the inner green

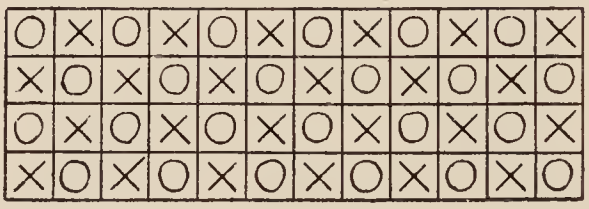


Fig. 2.

"beads," although it may point to a second grating inside on which they are received as on a screen.

The difference of appearance between the two sides of the valve is most characteristic and one not to be mistaken when once seen and noted, and is well shown on slides Nos. 12 and 13—No. 12 being the inner and No 13 the outer side of the valve.

As I have said before, the structure of the outer part of the valve is really divided into two—Nos. 2 and 3 in Fig. 1—but it is with the outer one of the two, as offering numerous examples of torn structure, we have chiefly to deal. I have been able, fortunately, to determine its character with absolute certainty, and also probably to obtain a key from it of the structure of the other two layers of the valve; but the results I propose to lay before you are so little in accordance with my theory of structure hitherto accepted by diatomists, that I can well understand any reluctance there may be to receive them as true. I certainly should have hesitated to accept them myself, had they not been forced

upon me by the continual work of nearly three years in a manner which left me no room to come to any other conclusion. My state of mind on beginning to work on a dry slide of *P. formosum* was one of utter bewilderment at the variety of appearances presented by the different valves, and my first impulse was not only to throw up the work, but also the microscope, in disgust, as giving no image of any structure which could be depended upon. After a time, however, I began to classify the appearances by observing that it was different sides of the same diatom presented to me, and, given the same side, the same appearance. After this my work became easy, and all my subsequent work a natural outgrowth from the labors preceding.

In coming before you with a brand-new theory of diatom-structure—as far, at least, as the *Pleurosigma* are concerned—I know the difficulties of the subject; how easy it is to mistake interference phenomena for new structure; how even the assumption by me of different layers would put me out of court on the laws

Fig. 3.

of these phenomena alone, did I attempt to base my theory on these appearances only. But I have made no such attempt, have never assumed the truth of any appearance until I have examined the structure causing it, by seeing it isolated from anything above or below. This I have been fortunate enough to do in numerous instances, and, after you have seen the results on the screen, will leave it with confidence to your judgment to decide whether I have been deceived in my conclusions or not.

The ultimate structure of the outer layer of the outer, or convex, side of *P. formosum* is seen in slide No. 9, and consists of a long fibril subdivided into short bars (Fig. 3), but how joined together I have not been able to discover. These fibrils are placed side by side lengthways on the valve, and run from end to end, and when perfect the appearance is as in Fig. 4, as plainly shown around the nodule in slide No. 11. When the structure is perfect, a white focal "bead" is formed in each of the larger interspaces and the whole run diagonally across the diatom, as in slides Nos. 5 and 13. On focussing inward you lose the bright

spots and come upon a grating running diagonally across the valve—as in slides Nos. 3, 6, and 8—and it will be seen that the holes of the diagonal grating lie immediately under the larger interspaces left between the fibrils. I believe these round white patches to be only ghosts, or, in other words, images of the inner layer thrown on the outer as on a screen, in proof of which I submit slides Nos. 7 and 8. In No. 7 the fibrils are distinctly seen running parallel to the median line, but only some of the interspaces are filled up, and on focussing down you discover the cause. In the under layer the holes are irregular in size, and it is only from the larger ones that the images are thrown. The outer layer often appears as if formed of definite squares, but I have no reason to believe there are any actual cross-bars, for directly the torn fibrils begin to diverge from each other, as in parts of slide No. 11 already referred to, cross-lines disappear.

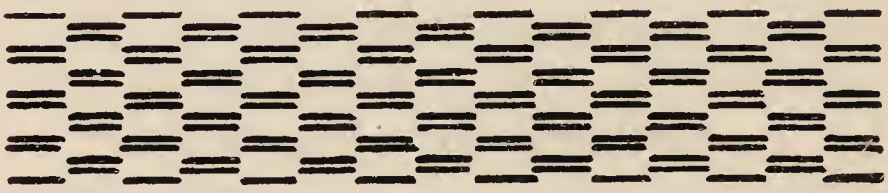


FIG. 4.

There is nothing to say, that I know of, against the idea of a regular grating; but when we get positive evidence to the contrary, a merely reasonable interpretation of appearances must give way to actual fact. It may be easily seen, however, on referring again to Fig. 4, how an appearance of cross-lines may be brought about.

Having done my best to establish the nature of the structure of the different layers of *P. formosum*, it remains to see how far the structure of the valves of the minute forms of this genus are identical with it. Similarity of form in itself should almost be enough to establish a unity of structure, and it satisfied myself a long time before I had obtained positive evidence to support it. But proof to one's self does not mean proof to others, and it was necessary to complete the evidence by offering sufficient examples of torn structure from each typical species to prove the identity. But before going on to this I would mention a few salient points common to all the *Pleurosigma*, and which hitherto seem to have

escaped attention. There is first the difference of curve between the two sides of the valve—flat on the inner and convex on the outer—common to all, and with it the different appearance presented optically; secondly, all the valves of this species characterized by diagonal "markings" have a row of coarser perforations running parallel to the margin of the valve, and also a row of similar ones on each side of the median line, making altogether four rows on the face of each valve; and, lastly, the nodule shows a characteristic difference on the two sides of the valve. On the one side it seems simply a cavity with the larger perforations running around, while on the other side it seems to be formed as a ring connecting the two halves of the median line. The four parallel rows, however, of larger perforations present the most characteristic features in common, and many of the specimens thrown on the screen from *P. formosum* downward will show them distinctly.

The finer specimens will mostly explain themselves, coming after *P formosum;* for convenience of comparison with which I have taken some of the latter at half the number of diameters, that the detail may appear of about the same minuteness as the finer forms Except that of *P. angulatum*, all my negatives have been taken from two slides of *P. formosum*, and for a long time I was unable to get any positive evidence of the finer structure of *P. angulatum* much different from the usual appearance, although there was no doubt about its resemblance in the general features to the coarser forms. But latterly I have been more fortunate, and am able to present a series of slides of that diatom which establishes beyond a doubt the identity of its structure with the other forms of the genus to which it belongs. Altogether, then, we have examples of four different species, differing vastly in size and shape, but in the finer structure all present the same features. I admit that examples of torn structure in the last three typical forms, although numerous enough to prove my point, do not offer the same extent of torn surface to study from as *P. formosum;* but, under certain circumstances, this would be scarcely possible. *P. formosum* has the structure twice as coarse as the other forms, and the mechanical pressure exerted on them in mounting being the same in both cases, what would be sufficient force to separate the fibrils only, and still leave them sound in the one, would

simply, in the others, smash them into bits so small as to be useless for purposes of investigation.

This is so generally; but in places enough of the structure is left intact to establish its identity, and I need not say that, having once found out what a chain is, there is no difficulty afterwards in proving that a link is a part of a chain, even if we can find no more than that link. In *P. formosum*, as we have seen, we find whole chains; in the finer forms only occasional links, but unmistakably belonging to the same sort of chain.

The first slides of *P. angulatum*, Nos. 35, 36, 37, and 38, are taken (three of them across the nodule) to show the different curves of the two sides of the valve; Nos. 35. 36, and 37 being from the inner side, and No. 38 from the outer. It will be seen that on the inner side the surface starts straight from each side and curves down towards the median line, while the outer starts straight from the median line and curves down towards each margin. The outer, or convex side, like the corresponding side of *P. formosum*, is the one from which all my torn examples are taken, and is absolutely identical in character; but beyond *P. decorum* I have been unable to discover any diagonal layer immediately underneath. The non-discovery of this may be due to two reasons: it may not exist at all, or the two may be so close together that even the little depth of focus of a wide aperture may be too much to allow them to be separated, in which case they would be microscopically non-existent. I have made experiments to this purpose on *P. formosum* with a dry apochromatic $\frac{1}{4}$-inch of .95 N. A, and found that the torn structure could not be seen with it when lying at the usual distance above the valve, but when the valve had sunk down—increasing the normal distance between the two layers—they could be seen readily enough; indeed, when floated off the valve altogether they could be seen with a one-inch of very moderate angle. I can offer no evidence, therefore, of the existence of a double layer on the outer side of the finer forms, although analogy may tell us there should be one, and must leave it at present as not proven.

The first two slides of the inner side, Nos. 35 and 36, taken on the same spot, will give you both squares and hexagons, and you must take your choice between them; for, having no exam-

ples of torn structure from that side of the valve, beyond a notched edge, I do not care to speak absolutely. Other examples, however, from the outer side, will show you how hexagons can be made, and you can form your conclusions accordingly.

Slides Nos. 40, 41, and 42 are taken at different focal planes on the same valve, which shows the surface abraded and two isolated fibrils running lengthways on the valve. The difference of appearance on the sound parts is considerable and varies from long rectangles on the upper focus to decided hexagons on the lower, while the only difference it makes on the fibrils themselves is just to thicken them a little. The same thing happens also on slides Nos. 47 and 48, taken with a little difference of focus, where we have squares on the upper and hexagons on the lower, while the free ends of the torn fibrils suffer but little change.

All my remarks up to now apply to the species having diagonal "markings" only; but the last slide of the list is taken from *P. balticum*, as an attempt to give a general idea of the difference of the structure between the two. Here we have still fibrils, but apparently of one continuous strand with swellings at regular intervals, which, lying side by side of the others, with the knobs nearly touching, give the appearance of squares.

In conclusion it may be necessary for me to say something about my methods of investigation, that no outstanding doubts may be left as to the correctness of my conclusions. This is all the more binding on me, as Dr. Cox has kindly told me that "I had need to tell the details of my examination so fu ly as to repel the possibility of doubt that the matter is in no sense illusory." I accept the invitation most cordially, as every practical microscopist will know that the method of investigation is everything.

First, as to illumination: I use a strictly central cone of light, collected first from the edge of the lamp flame by a bull's-eye condenser before being further condensed by the achromatic condenser. In this way I get a more intense illumination. Indeed, I found it impossible to differentiate some of the structure without it. My achromatic condenser is a dry one, and with the bull's-eye will give me all the light the lens will stand. In theory, of course, the whole of the aperture can only be utilized by the aid of an oil-immersion condenser. Granted the back lens of the combination can be only filled that way; but the

objective which can be so used without breaking up the image has yet to be made, in Europe at least.

The slides from which I have taken my examples are two slides of *P. formosum* and one of *P. angulatum*, mounted dry by Möller ; but I have verified my observations on a type-slide of *Pleurosigma* mounted by Thum, also on dry mounts by the same mounter and on a slide of *P. formosum* mounted in phosphorus by Mr. Stephenson, F.R.M.S., to prove there is nothing abnormal about the structure.

All my specimens have been tight on the cover, that the full available aperture of the lens might be used on them ; and in some instances, when there has been a doubt raised by others whether some of the appearances might not be due to some of the objects being off the cover, they have been tested by the vertical illuminator.

I have never taken a single photograph of any structure without thoroughly working it out visually first, that every point might be known to me before attaching the microscope to the camera ; and each hour's work there means six hours at least of previous investigation.

The question is sometimes asked, "What is a true focus?" and I admit that without certain landmarks the question is a puzzling one, as the image will keep repeating itself both in and out of focus. But to me those landmarks always exist, and in the structure I have been working at will be found in the leading features, such as the median line and the rows of larger perforations I have before mentioned. Thus, in comparing slides Nos. 35 and 38, the former gives what Mr. E. M Nelson calls the black dot, and the latter the white dot ; but a little higher focus on each will reverse them. The question then comes in, Which is right? and the answer is found in the median line with its two rows of perforations in one case and the margins in the other. In both cases you can reverse the image by raising the focus, but at the same time you lose the salient points of the valve. But, quite apart from this, there is a crispness and brightness about the image when at the true focus which cannot be mistaken by an expert.

The image of diatom-structure with an apochromatic is absolutely colorless, making the slides exhibited a true rendering of the appearances in the microscope—that is, with all the upper

layers; but where I have taken an under layer on the same valve, air comes between and the image has suffered—will, in fact, be recognized by you at once by its dull tone, and I wish you to draw no other inference from it but to see that there is another structure underneath.

On the slide No. 34 will be found in the centre a single layer of a fine species allied to *P. angulatum*, and at the side a part, I believe, of the same valve with the both layers intact ; and a study of the changes which take place in both on focussing up and down enables me to draw certain deductions, for my own guidance at least.

In the single layer there are no changes whatever beyond a change from a positive to a negative image up and down, and then the object vanishes altogether ; but on the other fragment there are six changes at least, proving the structure to be more complicated.

It will then, I think, be safe to argue that when the object under investigation changes from more than a positive to a negative image ; when, after losing, or almost losing it, you come upon another distinct image, either higher or lower, it proves this, at least : that the structure you are examining is a compound one, although I need not argue from it that the appearance you get is necessarily the true one.

The inference I would draw, then, from certain appearances on the surface, would be a limited one, but within those limits to be trusted. Thus, where you see squares or hexagons, it is not necessary that there should be squares or hexagons in the structure ; but it may be safely inferred that the recurring distances of the image represent the true distances of the actual structure. There is, in fact, with any legitimate use of the objective, no doubling and trebling of the lines as represented in influential quarters, but a correct rendering of distances if within the resolving power of the aperture, as shown by me in my "Note on the Abbe Diffraction Plate," published in the July number of the *Quekett Journal* for 1889.

Knowing my Abbe Diffraction Plate well, then, I have come to no conclusions on appearances only, and have formed no definite opinions on any structure until I have seen it isolated ; and can leave the results with all the more confidence in your hands.

LIST OF LANTERN SLIDES REFERRED TO IN THE PAPER "ON THE STRUCTURE OF THE PLEUROSIGMA VALVE."

BY T. F. SMITH, F.R.M.S.

1. *P. formosum.* Inner side of valve seeming to consist of a square grating, in which, when perfect, a focal image is formed in the alternate squares. × 1750.

2. The same. Same side, but another valve—one of the sides, from the margin inward, shows appearance when perfect. × 1750.

3. The same. Layer immediately under No. 4 on the outer side of valve, and seems to consist of a robust diagonal grating. × 1750.

4. The same. Layer immediately over No. 3, above the median line. The under structure has sunk down, leaving the long triangular bit adhering to the cover. × 1750.

5. The same. Layer on the outer side of the valve, sound. × 1750.

6. The same. The diagonal grating immediately under, sound. × 1750.

7. The same. Same layer as No. 5, but images showing in patches.

8. The same. Grating immediately under showing cause of patchiness. The holes in under grating are either some of them stopped up, or all the parts of the grating are not on the same level.

9. The same. Ultimate structure of layer No. 4, consisting of short bars of silex arranged as an irregular fibril. × 1750.

10. The same. Ultimate structure arranged on the valve, but stripped off in places. The diagonal lines represent the No. 3 grating underneath, out of focus. Note how the bright focal spots are caught between the fibrils. × 1750.

11. The same. Same structure arranged to form squares around the nodule. It will be seen that in some places the appearance is that of a square grating with well-defined cross-bars, but when the fibrils diverge from each other the cross-bars are lost. I am inclined to think the cross-bars an optical illusion. × 1750.

12. The same. Inner side of valve, same as No. 1, magnified 875 times only, that the detail may appear of the same size as the smaller species, such as *P. angulatum*. This valve is perfect and does not show the grating except at one edge. On focussing inward all the white interspaces form into green "beads." × 875.

13. The same. Outer layer, same as No. 4, perfect. Median line appears at the edge, but on focussing down that part of the valve is seen shelving down, showing the outer side of the valve to be V-shaped in section. × 875.

14. The same. Torn structure from same side, some of which has floated off from the valve altogether. Note the diagonal lines underneath. × 875.

15. *P. angulatum* (?). Same side, but another valve. Note fibril where marked with a cross, to compare with same structures on finer specimens. × 875.

16. *P. decorum*. Outer side. Underneath is the same diagonal grating, which I have not figured. × 1750.

17. *Pleurosigma* sp. Small species shown where marked with a ×. This is the species from which the next nine slides are taken.

18. The same. Under layer, with a hole clean through in one part. × 1750.

19. The same. Same valve, outer layer, with fibrils projecting over part of hole. × 1750.

20. The same. With torn fibrils, outer layer. × 1750.

21. The same. Under layer of same valve, showing long strip and hole torn out, which the fibrils shown on No. 20 have bridged over. × 1750.

22. The same. With bit chipped off the edge and fibrils lying loose. × 1750.

23. The same. With fibrils unravelling. × 1750.

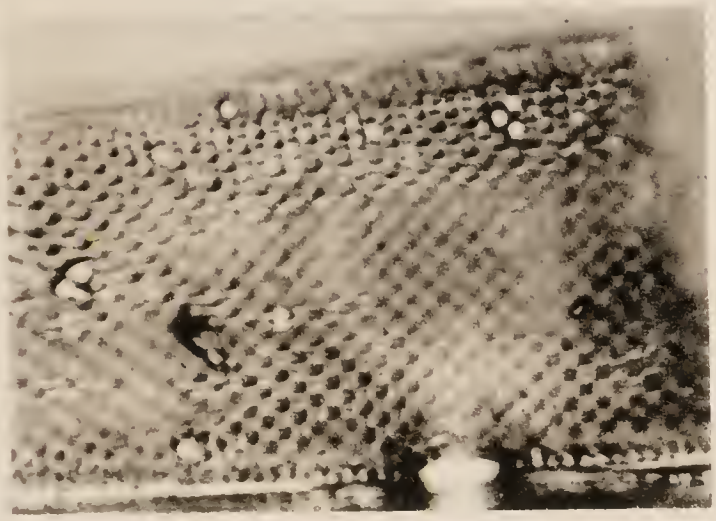
24. The same. Another part of same valve. × 1750.

25. The same. Surface abraded, and showing fibrils on parts of valve. × 1750.

26. The same. Inner side of valve, corresponding to No. 1 layer of *P. formosum*. × 1750.

27. *Pleurosigma* sp Specimen marked with a ×, and the same species from which the next six slides are taken.

1



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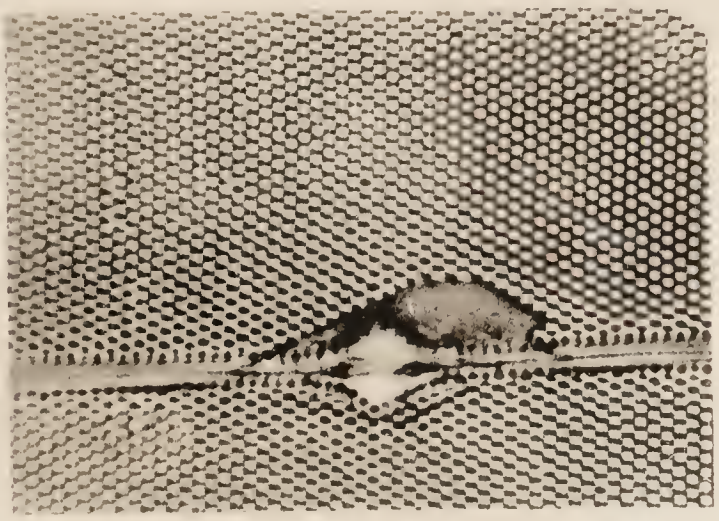

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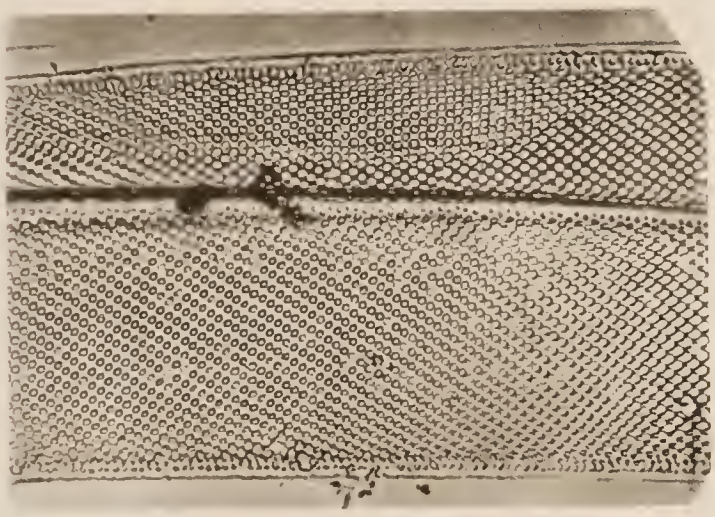

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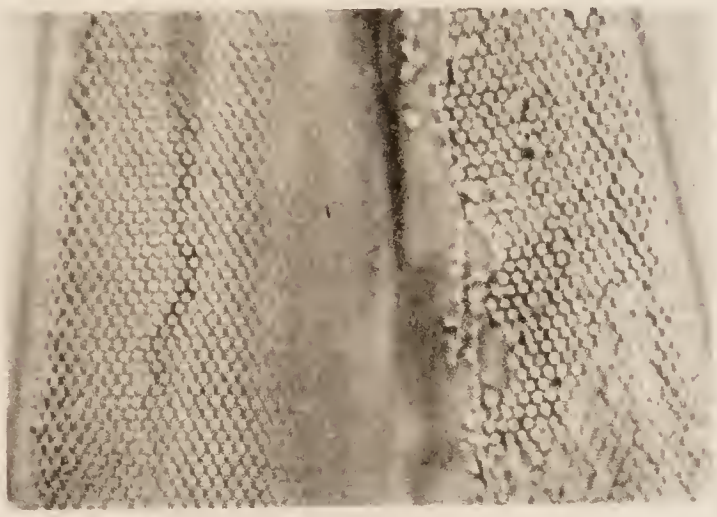

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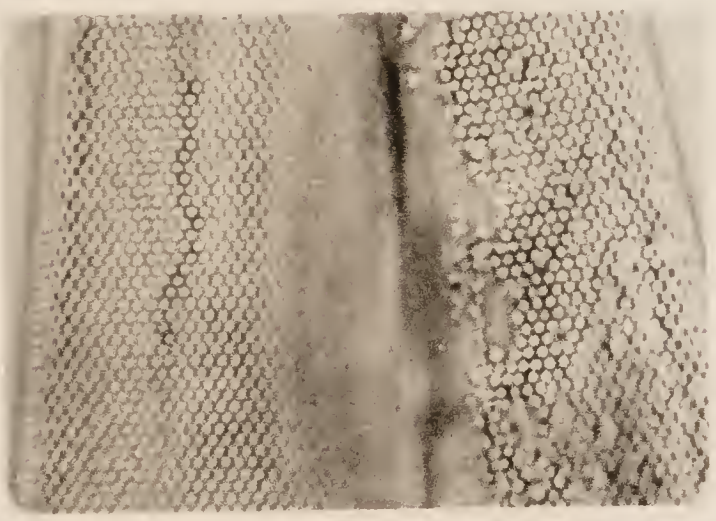

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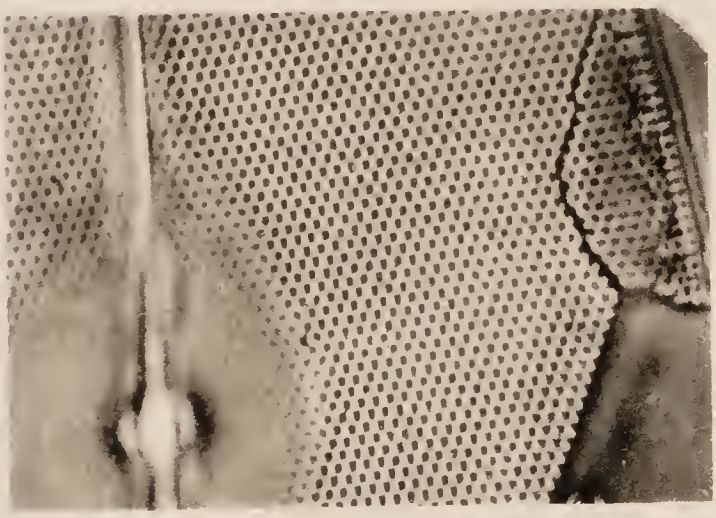

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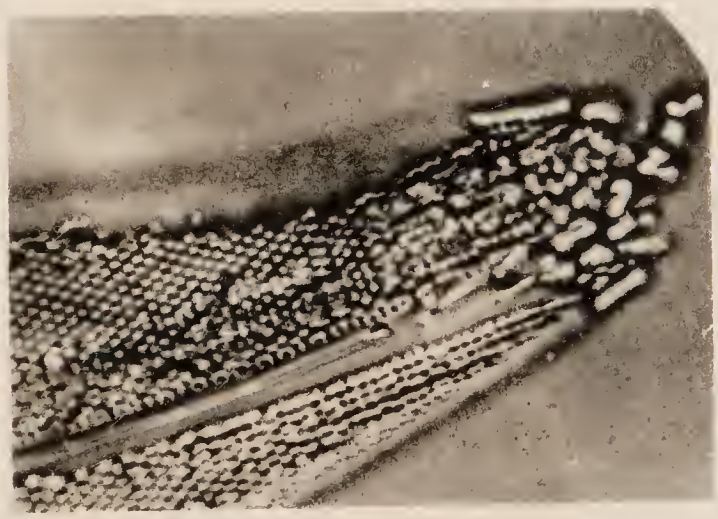

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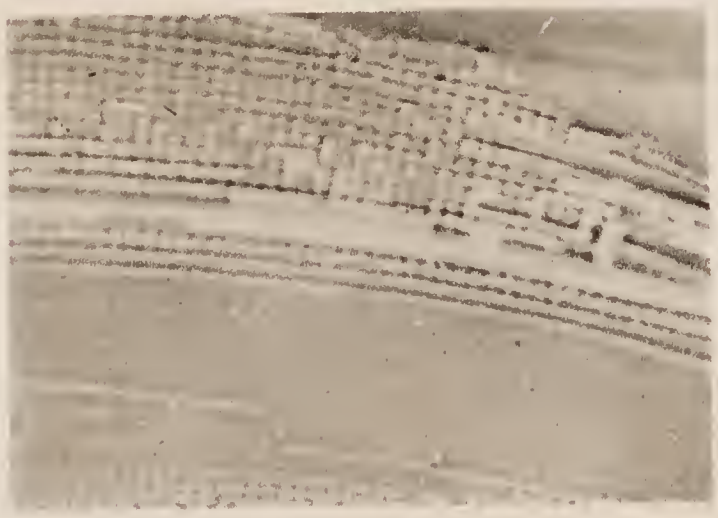

T. F. SMITH ON THE STRUCTURE
OF THE
PLEUROSIGMA VALVE.

28. The same. Outer side with torn structure. × 1750.

29. The same. Layer immediately underneath. × 1750.

30. The same. Showing the two layers at one view. × 1750.

31. The same. Layer underneath. × 1750.

32. The same. Outer layer, showing fibrils, perfect but only occasional focal images. × 1750.

33. The same. Layer underneath. × 1750.

34. *Pleurosigma* sp. Single under layer of a fine species of a *Pleurosigma* detached from the outer. At the side will be seen a part of the same valve, I believe, with the both layers complete.

35. *P. angulatum.* Inner side, showing curve straight from each margin and sloping down towards the nodule and median line. This plane shows square. × 1750.

36. The same. Same part taken at a little lower level to show hexagons and intercostals. × 1750.

37. The same. Same side, but another valve. × 1750.

38. The same. Outer side, showing curve straight from nodule and median line, and slopes down towards the margins. N. B.—Structure on this side corresponds to No. 4 slide of *P. formosum.* × 1750.

39. The same. Same side, showing longitudinal crack with fibril bridged across it in one place. × 1750.

40. The same. Surface abraded and two fibrils left isolated. × 1750.

41 and 42. The same. Same spot, but at a little lower focus to show changes in appearance on sound parts of valve. The changes on the surface are considerable, while the fibrils themselves change but little, except to thicken. The last is the lowest of the three and the appearance hexagonal. × 1750.

43. The same. Same side, showing—where marked with a ×—two fibrils joining together to form the regular structure. × 1750.

44. The same. Same side—end of valve—shows isolated fibrils in places. × 1750.

45. The same. Same side, torn structure. × 1750.

46. The same. Slide of *P. angulatum.* The specimen marked with a × is the one from which the next three slides are taken.

47. The same. Torn structure, showing free ends of fibrils.

48. The same. Same bit taken at a little lower level to show hexagons on sound parts. Note that but little change has taken place in the torn part, on account of there being no interference from structure below. × 1750.

49. The same. Same valve, showing under layer. The part immediately under the torn structure has been torn off and pushed down, leaving a considerable distance in that place between the two layers. × 1750.

50. *P. balticum.* The fibrils here seem to be in long strips and thickened out at regular intervals, giving the appearance, where they approach each other, of a square grating. Indications also are given on the slide of the lower layer. × 1750.

DIATOM-STRUCTURE—THE INTERPRETATION OF MICROSCOPICAL IMAGES.

BY JACOB D. COX, LL.D., F.R.M.S.

(*Read January 2d,* 1891.)

Mr. Smith's paper and his photographs are a valuable and interesting contribution to the discussion not only of diatom-structure, but incidentally of the interpretation and value of microscopical images.

The discussion of the structure of the diatom-valve turned, for a long time, on the question whether the dotted markings were caused by solid spherules or hemi spherules of silex or by areolæ or alveoli in the shells. Elaborate rules were formulated by which it was supposed the examination should be so conducted as to decide indisputably when a dotted appearance was caused by the one or the other structure. The study of the fractured edges of broken shells, aided and illustrated by photography, may be said to have settled this question in favor of the alveolar structure some years ago. This done, we were prepared for the next question, which was whether these alveoli are capped by a very thin silicified film on one or on both sides of the shell. Are they or are they not cellules in the shell, completely enclosed by a silicified membrane? Without asserting that this is definitively settled, it may fairly be said that the prevalent opinion now is that the alveoli are thus completely enclosed, but that the extremely thin membranous caps are not so solidly silicified but that endosmose acts through them and the plant is nourished in this way.

The next step in the discussion is the inquiry whether the alveoli are interior cavities in a single homogeneous membrane, or is the shell formed of two or more membranes. In the more robust kinds it was demonstrated that there were at least two plates or membranes in the shell. The larger *Coscinodisci* were often found with the inner film, containing the so-called "eye-spots," separated from the outer part of the shell; this inner film being much thinner than the outer, and nearly flat, the shallow depressions at the eye-spots being surrounded by a hexagonal tracing which marked the place where the walls of the comparatively deep cellules had been attached. The outer film or plate consists, apparently, of stout hexagonal structure capped on the outer side. In several species this outer side has a secondary marking of finer dots within the larger hexagons. In *Triceratium favus* the *inner* film is that which has the secondary marking, consisting of very fine dotted lines radiating from a common centre and continuous over the whole shell. There can be little doubt that these finer, secondary dots are analogous to the larger ones and are indications of a pitted surface. In these coarser forms it is quite conceivable that the structure should consist of three plates, viz., an outer and an inner plate, each nearly flat,

and an intermediate one consisting of a hexagonal grating or a plate perforated with holes. The three in apposition would constitute the shell with its alveoli. As a matter of fact, I do not know that more than two such plates have yet been discriminated as components of the diatom-shell, and my present belief is that there are but two, unless Mr. Smith's investigations shall establish a third. As I understand his observations, they are consistent with the foregoing general theory of the shell-structure, and are the basis for a theory of a fibrous film exterior to those above described and superposed upon them. To this I shall presently return.

That the structure of the diatom-shell is the same in very thin and finely marked species as in the more robust, has always seemed probable to investigators, and the argument from analogy has been used with confidence. This, however, has not been allowed to discourage the study of the finer forms, and the improvement of our glasses has been utilized by bringing finer and finer details under direct observation. The separability of the shell into two plates has been noted not only in small and finely marked *Coscinodisci*, like *C. subtilis*, but in the *Actinocycli*. In *Pleurosigma* (*P. formosum*, *P. angulatum*, and *P. bâlticum*) the broken margin showing what Mr. Smith calls the "postage stamp" fracture has been seen and photographed, and in a number of photomicrographs of my "broken-shell series" (June, 1884) I showed this and what I regarded as separated upper and lower films of the valve of *P. angulatum* in the same specimen.*

Such being the state of our knowledge and theory on the

* In a summary at the end of a series of articles on "Structure of the Diatom-Shell" in the *Am. M. M. J.* (March to June, 1884) I said, p. 109:

"1. The diatom-shell is usually formed of two laminæ, one or both of which may be areolated, and may be strengthened by ribs, which have been described both as costæ and as canaliculi.

"2. The normal form of the areolæ is a circle, and these when crowded together take a hexagonal and sub-hexagonal form.

"3. The areolæ are properly pits or depressions in the inner surface of one of the laminæ, so that when two laminæ are applied together the exterior surfaces of the shell thus formed are approximately smooth and the cavities are within.

"4. The apparent thickening on the exterior of the lines bounding the areolæ in some species, as *Eupodiscus argus*, etc., is not in contravention of, but in addition to, the formation above described.

"5. However fine the marking of diatom-valves may be, the evidence from the color of the spaces between the dots and of the dots themselves supports the conclusion that they follow the analogy of the coarser forms, in which both fracture and color are found to prove that the dots are areolæ and the weaker places in the shell."

subject, Mr. Smith determined to try what could be learned by the systematic and careful use of the Zeiss apochromatic lenses under such conditions as to sub-stage illumination, by means of a wide-angled condenser, as should give the new objective the fullest scope for its power and quality. His conclusions from this examination he has kindly laid before us, so fully illustrated by beautiful lantern slides and prints that we can have little doubt as to the *appearances* on which the conclusions are based, except as to color.

In such a case the real question is one of interpretation of appearances seen under the microscope, and what I have to say will bear chiefly on this point, with direct application to the study of diatoms.

All microscopists are acquainted with the position of Prof. Abbe in regard to images formed by diffraction. As commonly stated it amounts to a declaration that all microscopical images of structure with details smaller than .0005 of an inch are diffraction images from which the true structure may be argued, but which cannot be taken as in themselves true representations of the structure. "The resulting image produced by means of a broad illuminating beam," says Prof. Abbe (*R. M. S. Journal*, December, 1889), "is always a mixture of a multitude of partial images, which are more or less different (and dissimilar to the object itself)."

This theory has been very vigorously assailed by Mr. E. M. Nelson, of London, from the practical and experimental side. In a paper read before the Quekett Club in May last, entitled "The Sub-stage Condenser: Its History, Construction, and Management; and its Effect Theoretically Considered," Mr. Nelson asserts that the cone of light from a sub-stage condenser "should be of such a size as to fill $\frac{3}{4}$ of the back of the objective with light; thus N. A. 1.0 is a suitable illuminating cone for an objective of 1.4 N. A." He says that "this opinion is in direct opposition to that of Prof. Abbe," and to maintain it he denies the truth of the diffraction theory as applied to microscopical images. He says of it: "The diffraction theory rests on no mathematical proof—in the main it accepts the physical law of diffraction; but on experiment it utterly breaks down, all criticism is stopped, and everything connected with it has to be treated in a diplomatic

kind of way" (*Quekett Club Journal*, July, 1890, pp. 124, 125). I state Mr. Nelson's position without any purpose of discussing it, and only to point out that it is this to which Mr. Smith refers in his paper when he says: "This capacity of standing more light was pointed out from the first by Mr. E. M. Nelson, but has not received the attention it deserves, and the neglect of this point has stultified the efforts of many microscopists, both here (in England) and on the Continent, to get more out of the new glasses than the old objectives."

Mr. Smith's investigation of diatom-structure is thus closely connected with Mr. Nelson's views and experiments upon the diffraction theory. Both will challenge the attention of practical microscopists as well as physicists. I have not gone far enough in my own investigations to warrant me in expressing a judgment on the questions involved ; but I would urge every microscopist to make his ordinary work the occasion for accumulating evidence which may help settle the very important debate. My suggestions are only such as are based upon the well-known history of diatom-study and my own experience. They are offered by way of clearing the field by pointing out the limits of the discussion and the known facts which ought to be kept firmly in mind in all such investigations.

It is no reproach to the microscope as an instrument of investigation that there are limits to its powers and capabilities. Such limitations are common to all methods of investigation. If, trusting to my natural eyesight, I am trying to make out the meaning of appearances on a distant hillside, I find at once that all perception by the sense of sight is an interpretation of visual phenomena which are not in themselves decisive. They may lack clearness by reason of the mist in the air. They may be obscured by something intervening, like foliage, or may be partly hidden by inequalities of surface. A thousand things may prevent clear and easy interpretation of what I see. I may have to change my point of view before I can reach a conclusion, or even have to go to the object itself. If I cannot do this I may be left in abiding doubt as to what I have seen.

Microscopical examination is precisely analogous to this. If I am examining a mounted object, I am tied to one point of view. I cannot approach nearer, and cannot do more than note the

visual appearances and make theories to account for them in accordance with facts already learned. We try to vary the conditions as much as we can ; we change our objectives ; we try central light and oblique light ; we examine one specimen dry and another in a dense medium ; one by transmitted and another by reflected light ; but when we approach the limit of minuteness of object or detail which our instruments will define, we are in the same situation as when using our natural eyes across a chasm, neither better nor worse ; we have to account for what we see by a reasonable hypothesis which will make it take an intelligible place amongst natural objects.

Our skill as microscopists, apart from the technical dexterity in the use of our tools, consists largely in devising varied experiments and changes of condition, so as to enlarge the body of evidence from which we draw our inductive conclusions. To assist ourselves in this, we also catalogue such facts and methods, and such cautions and warnings, as our experience (or that of others) has taught us. Let us look for a moment at some examples.

We know very well that we are liable to illusions of sight, so natural and so powerful that even the intellectual certainty that they are illusions will not destroy them. If we are looking through the Abbe binocular eyepiece, using the caps with semi-circular openings, we see a hemispherical object as if it were a hollow bowl, and, visually, it refuses to be anything else. But this is not peculiar to microscopical vision, for we do an analogous thing with the stereoscope, and by wrongly placing the pictures may make an equally startling pseudo-perspective.

We find that what we call transparent bodies are full of lines as dark as if made with opaque paint, and throw far-reaching shadows. But I see similar ones in the cubical glass paper-weight on the table before me, and know that by the laws of refraction the surface of a transparent body is always dark when its angle to the eye is such as to cause total reflection of the light in the opposite direction. By the same law we know that if the angle of total reflection in the same transparent cube were differently placed with regard to the eye, the now dark surface would become a mirror, reflecting the sky and distant objects as brilliantly as if silvered. Our diatom-shells give us constant experience in these phenomena. A prismatically fractured edge

will scintillate so as to defy all efforts to define its outline. Reflected images look like actual details of structure in the object. Dealing, as we constantly are, with objects made of glass, we have constant use for our reasoning faculties to determine the meaning of all these refractions and reflections, which sometimes are almost as confusing as the broken images seen through the glass pendants of a chandelier.

In addition to these familiar effects of refraction and reflection, we have the class of phenomena which we call diffraction effects. These may be wave-like fringes of light and shadow following the outline of the transparent object and reduplicating this outline; or they may be analogous fringes thrown off the sub ivided parts of the object, as from the cup-like outline of alveoli, or from some projecting rib or groove like those along the diatom's median line.

We know by constant experience that when we throw light obliquely through a transparent reticulated object like a diatom-shell, the diffraction fringes from the separate alveoli run together across the shell in dark striæ oblique or at right angles to the direction of the light. In the *Pleurosigma*, in which the rows of alveoli are oblique to the midrib, we very easily get the oblique striation by the use of oblique light; getting both series of lines at once, one only, or one strong and the other faint, as we please and with very little trouble. We get, with a little more pains, a transverse striation, at right angles to the midrib, which is fainter because it proceeds from alveoli not so closely connected in rows. It may be called a secondary striation. With still more effort we may get a much finer and fainter striation, parallel to the midrib, by throwing light at right angles to it or nearly so. By lamplight, and with objectives not apochromatic and not exceeding the aperture of 1.0 N. A., these lines are usually in patches, upon spots here and there, longer (in the length of the shell) than they are wide. But with sunlight this tertiary diffraction striation may be made to cover the whole surface of *Pleurosigma angulatum* by an exquisitely fine longitudinal grating over its whole surface, as was demonstrated by Dr. Woodward in one of the most striking of his photomicrographs in what is called "the Abbe experiment."* As the improvement in our lenses, both by increasing

* See R. M. S. Journal, vol. ii. (1879), p. 675; see also M. M. J. xvii., p. 82.

their angle and by the apochromatic system, tends to make visible by lamplight what before could only be seen by sun, we should expect that something like the fibrillæ shown in Mr. Smith's photographs would be visible. Finding it would not prove that it is purely the result of known laws of diffraction; but it justifies a cautious and scientific scepticism in receiving a new explanation until we have repeated the experiment often enough and under such varying conditions as to exclude doubt.

As we increase or reduce the obliquity of the light in examining *Pleurosigma formosum*, we know that the alveoli are distorted (or may be) in varying ways and directions. Some of these are figured in "Carpenter on the Microscope," but they are only a few of a numerous series. Whoever will experiment a little may satisfy himself that the permutations and transmutations of the diatom markings may be made little short of kaleidoscopic. Hexagonal markings may become square and may have short lines running off from one angle. These lines may be lengthened and the square or hexagon reduced to a dot, so that the appearance of the surface may be that of oblique series of parallel dashes. The direction of these lines depends on the direction of the light, making a series of gratings, of which the prevalent character may be oblique in either of two directions, transverse or longitudinal. The so-called intercostal points may be enlarged and brightened until they become the most prominent marking, and the alveoli proper may be diminished to insignificance. These appearances are so like many of those in Mr. Smith's series that we, who can only see the print and cannot get our fingers upon the fine adjustment of the microscope and note for ourselves the effect of a change of focus, are necessarily made cautious in accepting his interpretations; but there should be caution in rejecting as well as in accepting, and he fairly challenges us to repeat his investigations under similar circumstances and with similar objectives.

An examination of his print No. 12 with a hand lens will illustrate what I am saying. When looked at with the naked eye, this print shows a long patch of longitudinal striation on the lower side of the valve. Immediately below the midrib we see the coarse, oblique dotting peculiar to *Pleurosigma formosum;* but if we use the lens we see at once that, in the patch referred to, the dots are twice as numerous as the alveoli of the shell. The

interpolated ones (proceeding from above downward) are at first very small, then larger but rectangular and twice as long as wide, making the pattern one of alternate dots and rectangles; as we pass to the right the rectangles run into each other obliquely, making a wavy white line, the dots of the alveoli proper being in the bends of the line, very much as in the longitudinal fibrils of print No. 11. This change, distortion, and multiplication of the dots is so entirely within our common experience in diatom-study that I have no hesitation in explaining the longitudinal striated appearance in this patch as the result of the reduplicating of the dots by the intercalation of the rectangular ones, making in fact broken lines which on so small a scale are sufficiently even to make continuous ones to the naked eye. On the other side of the midrib in the same print (No. 12) the rectangles and round dots are of nearly equal size, but they still make a faint longitudinal striation, diverging a little from the midrib as we pass from left to right.

We thus have an ocular demonstration how a striated appearance may be made out of a tessellated one, when there is no question of continuous fibrils. Yet even this does not prove that the fibrils are not there. Of course all visual appearances under the microscope have their cause in the structure of the object, considered in relation to the laws of transmitted and reflected light. The puzzle often is to tell what to attribute to each factor. I do not think it difficult to account for the tessellated appearance of dots and squares with alternate blue and red color. To do so may require us to refer to some elementary matters in diatom-marking.

Dr. Brebisson, at a very early day, divided the regular dotted markings of diatoms into three classes: 1, *Quadrille rectangle droit* (in squares parallel to midrib, e.g., *Pleurosigma balticum*); 2, *Quadrille rectangle oblique* (in squares oblique to midrib, e.g., *P. formosum*); 3, *Quinconce* (quincunx or lozenge of 60° smaller angle, e.g., *P. angulatum*). This classification has been a good deal neglected, but has good claims to remembrance, and will assist me in explaining the phenomena before us.

In Mr. Smith's print No. 6 is well shown what I regard as the normal scheme of areolation of *P. formosum*. It will be seen to be a reticulation with meshes as nearly square as nature gives us

in growing things. If the corners of these meshes be filled up, the included circles will still keep to each other the relative position of Brebisson's oblique quadrille. The diminution of the round alveoli would not need to proceed far before the approximately rectangular mass of silex between the circles would be about as large in diameter as the circles themselves. Under the laws of optics, which we have already seen illustrated in print No. 12, the tendency of approximately rectangular details is to become more strictly so in the microscopical image. In Figure 1 I have illustrated this by a geometric diagram of which one half shows the square reticulation, and the other the resulting tessellation of solid squares and round alveoli when the walls are thickened and the corners filled up. It will be noticed that when the

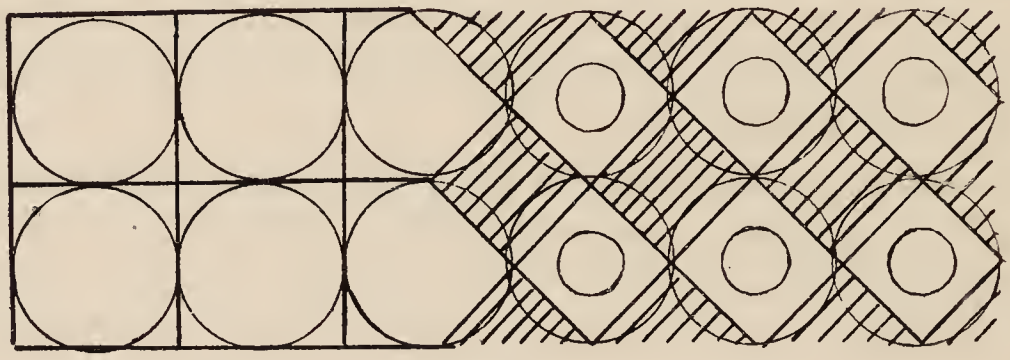

FIG. 1.

corners are so filled as to make the alveoli circular, the interspaces are approximately square, and, being solid, will be red or pink by transmitted light when the alveoli are bluish-white. On the inner side of the shell the thin circles, or "eye-spots," are usually smaller than on the outer side; the diffraction effect by transmission of light will straighten the edges of the tessellated outline; the squares will each have half the area of, and will be diagonal to, the original squares; and with their alternate colors we shall have exactly the appearance which Mr. Smith describes, and which is very well shown in prints Nos. 1 and 2, compared with No. 6.

The peculiarity of the quincuncial arrangement of alveoli is that when the circles crowd upon each other so as to become polygons bounded by straight lines, they form hexagons instead of squares, and even when they are circles in a continuous plate of silex the hexagonal outline is a persistent ocular illusion. We should expect, therefore, that the tessellated appearance with

equal squares of red and blue would be a mark of *P. formosum* as distinguished from *P. angulatum*, under proper conditions of illumination and examination.

We are justified in concluding, therefore, that the phenomena of color and form thus examined are not only consistent with, but strongly confirm, the generally received theory of diatom-structure, and cannot be said to indicate anything new in that direction.

Mr. Smith also expresses the opinion that only by means of a wide-angled objective, and illumination by a wide cone of light from the sub-stage condenser, can the upper and lower films of a shell like *P. angulatum* be discriminated. As he recognizes some photographs made by me, and deposited with the Royal Microscopical Society in 1884, as showing this discrimination, it is due to scientific accuracy to say that they were made with a Wales $\frac{1}{15}$ water-immersion objective of about 1.0 N. A. aperture, and with a *narrow* cone of light coming from a Webster condenser under the stage having a diaphragm with a $\frac{1}{4}$-inch opening behind it. Mr. Smith's own objects photographed could not be illuminated with a very wide cone of light, as they were mounted dry and he tells us he used his condenser dry. There was therefore a stratum of air both above and below the slide on which the object was mounted, and the illumination could not exceed the "critical angle," 82°, in passing through the cover glass, and must in fact have been considerably less.*

In my own experience I have found a broad cone of illumination unsatisfactory, for the same reason that I have found oblique light in one direction unsatisfactory. It is almost impossible to centre the sub-stage condenser so accurately that a wide cone can be trusted to be central. If you centre it by examination with a low power, it is almost certain that it will not be centred for a high power, for two objectives are rarely centred alike. The field, under a magnification of 1,750 which Mr. Smith has commonly used, is so small that the least decentring will illumi-

* In my note book, June 3d, 1884, I find that I entered my observation of one of the broken shells which I photographed, as follows: "A remarkably interesting fragment of *P. angulatum*, showing partial removal of one film, and fracture through dots over a large space." In preparing this paper I have repeated the examination with the objective named, and find the distance between upper and lower film easily appreciable in focussing.

nate it only by the oblique rays from one side of the cone, and we then immediately get diffraction effects. I am bound in candor to say that in most of Mr. Smith's prints I recognize similar effects to those which, in my own work, I attribute to oblique light. It may be that, with improved contrivances to secure exact centring of objective and condenser, we shall find advantages in the use of the wide cone. I speak now only of my own experience under existing methods. The slightest turn of the mirror on its axis will change light from central to oblique; and I suppose we are all in the habit of doing this, so as purposely to throw light through one side or segment of the condenser for the purpose of studying the effect on an object of the changing direction of illumination. So unstable a source of light prevents our knowing very exactly when the light is strictly central, and makes it hard to return to any exact condition from which we have departed even a little. These considerations have kept me (perhaps mistakenly) in the practice of using the narrow cone of light for photography, reserving my oblique light for special resolutions of striation and for the professed study of changing effects.

Similar reasons have made me distrustful of dry mounts when high powers are to be used upon any but the thinnest objects. Refraction, and attendant diffraction, are so increased with increase of index, or rather increased difference of index, that it has grown to be a maxim with me to have the mounting medium and the object as near alike in index as is consistent with the discrimination of structure. The pale images of transparent objects are those I find most truthful, for paleness is consistent with good definition and resolution, whilst the brilliant pictures are apt to be glittering deceptions. I fully admit, however, that it may well be that with improved glasses we may add to the extent of details visible upon a surface, like that of a diatom-shell, and that it is possible that mounting in most media would obliterate the finest of these details. To a certain extent we are all familiar with this. A rather coarse dry shell like *P. balticum* will have its details instantly obliterated if water from the immersion of our objective penetrates beneath the cover glass Mr. Smith's print No. 50 might pass as an excellent reproduction of this

effect, the fluid passing along the structural lines, obliterating part and leaving part.

But when full weight has been given to all these things, and we have put aside those of Mr. Smith's long and beautiful series of photographs which are liable to our criticism, there still remain several which cannot be thus disposed of.

Prints Nos. 14 and 15, taken with half the magnification of most of the others (× 875), show strips of surface marking which strongly support Mr. Smith's interpretation, viz., that the outer surface of *P. formosum* is covered by a longitudinal series of fibrils separating so as to pass round the alveoli and uniting over the solid corner interspaces. The definition in these cases is not only reasonably clear and free from the ordinary marks of diffraction effects, but, most conclusive of all, there is in No. 15 a bit of this film floated off the shell and lying detached by its side. The fibrillar structure of this bit leaves little room for scepticism, and it so exactly accords with the appearance of the similar fibrils remaining on the surface of the shell that I cannot refuse to accept it as evidence of structure. Going back from these to print Nos. 10 and 11, we now find reason to accept these also as evidences of the same structure, though distorted by obliquity of light, so that they would not have been satisfactory taken by themselves. On No. 5 also we may recognize some of the same fibrils. The single detached fibril in No. 9 is not so directly connected with any other specimen, either in the photograph or in Mr. Smith's description, as to present the evidence on which it is shown to be part of the same structure; but the measurement of its flexures so corresponds with the areolæ of the shell that its probable connection with a similar valve may be assumed.

The interpretation of this structure which seems to me most satisfactory is to regard these fibrils as superposed upon the general surface of the shell as a protection to the thin capping of the alveoli against abrasion. It would, in that case, come under the description of those appearances which I have referred to in paragraph 4 of my general summary (see foot-note, p. 75 ante), viz., a "thickening on the exterior of the lines bounding the areolæ . . . which is not in contravention of, but is in addition to," the usual formation of the shell by means of two principal plates or films. All the species of *Pleurosigma* which have the

alveoli arranged in Brebisson's *quadrille* seem to have strengthened ribs between the rows of "dots"—*P. balticum*, *P. attenuatum*, etc, have them longitudinal and straight. Mr. Smith's observations seem to prove that *P. formosum* and its congeners have them longitudinal but wavy, which is a positive addition to our knowledge, since we should naturally have expected them to be oblique. The appearance of the finer square tessellation in either of the principal films of an obliquely marked *Pleurosigma* would seem to prove it to belong to the "quadrille" marked class, and I think the smaller forms which Mr. Smith has left unnamed may be identified as *P. obscurum* W. Smith, which is probably only a small form of *P. formosum* or *P. decorum*.

I do not find in the prints any conclusive evidence that the quincuncial marked species, as *P. angulatum*, have the same series of fibrils. No one doubts that all have a vegetable membrane in which the silex is deposited, and, under favorable circumstances, a fracture through a row of dots would leave the thicker connecting membrane looking approximately like a fibril. The argument from analogy is not as strong here as in the case of the "quadrille" marked kinds. The structure *may* be found in all, but the evidence does not yet seem complete. There is here a good field for further investigation.

This leads me to say that the size of the fibrils shown by Mr. Smith does not seem to me so minute that any good $\frac{1}{10}$ or $\frac{1}{15}$ objective should not define them. We must remember that the condition of an object may count for much in the resolution of its structure. A thickly silicified shell may not show what an imperfectly silicified one will demonstrate: The former will break into small angular bits with a mineral fracture; the latter may separate into threads or membranes. The floating off of the fibrils in print No. 15 seems to show that the shell was in a peculiar condition; a sort of dissection of an uncommon kind having taken place naturally or artificially. It would be an interesting experiment to subject various species of *Pleurosigma* to the action of hydrofluoric acid for varying periods, and then mount them for examination. To extend Prof. Bailey's old experiments in this direction would be very useful; but the danger of injury to the objective is such that it would hardly be advisable to watch the action of the acid under the microscope.

If I seem to have reduced the new matter in Mr. Smith's observations to a minimum, I should not do justice to my sense of the real value of his work unless I add that enough remains to make it, in my judgment, a very important and interesting step in the investigation of diatom-structure. It is also full of promise that still further results may be attained by pursuing the investigation on the same line. I am confident, therefore, that the Society will join with me in expressing a sincere sense of obligation to him for communicating the results of his observations, and especially for the valuable aid in understanding them which is given by his beautiful series of lantern slides and prints.

THE WORK OF THE MICROSCOPE.

ANNUAL ADDRESS OF THE PRESIDENT, P. H. DUDLEY, C E.

(*Read January 16th*, 1891.)

At no period in the history of the microscope have the results of its researches received as much attention as at the present time. The importance of the investigations in recent years, by its means, of many of the causes affecting the health and comfort of mankind, is just being recognized by the efficacy of the remedies which have been suggested from a knowledge of the causes. The indications of a new remedy are daily flashed from continent to continent by that unseen agency, electricity, its messages multiplied by the press in all languages and distributed through the land by steam's swiftest trains. These three great inventions of communication and diffusion of knowledge of to-day have carried the tidings to the peoples of all nations, and there is a common interest and thought upon the subject. History does not record a grander spectacle than that of the entire civilized world, brought into sympathy and interest by the investigations of the microscope, in search of relief for thousands of its sufferers from some of the occult conditions incident to life.

Animal or plant life, either of the highest or lowest orders, is surrounded by conditions, some favorable to growth, others unfavorable; and whether an animal or plant will survive or perish, aside from the inherent vitality, depends upon the preponderance of the favorable or the unfavorable conditions of environment.

This law is coeval with the existence of life. To ascertain and understand the conditions favorable to the human race has and will always occupy the attention of a large portion of the more intelligent of mankind.

Some of the conditions are at once apparent; others, equally important, are unseen, obscure, and only discovered by tracing back from the effect to the cause. We experience effects and not causes, and to analyze the former, assigning each to its proper cause, is by no means an easy matter. The first step is to observe the facts, study their relations, and trace the laws controlling them. It is only in this way that any progress has been made, and then oftentimes the real nature of the cause remains undiscovered.

Jenner's important discovery of vaccination for small-pox, a century since, was not the result of accident, as often stated, but close observation of a series of facts and studying their relations. That small-pox was due to a germ in the system, invisible to the keenest vision, is of recent demonstration by the microscope.

How early minute forms of life were suspected of causing bodily ailments or decomposition in fluids is uncertain. The Egyptians, 3,500 years since, knew how to practically prevent decomposition in bodies and wooden utensils, so that they have been preserved to the present time. More recently Robert Boyle, 200 years ago, expressed the opinion that ferments had something to do with fevers. Leuwenhoek, 1632 to 1723, made small lenses, and described the ferment of yeast as ovoid or spherical bodies, and discovered bacteria in the mouth and in fluids undergoing decomposition. The powers and use of the early simple microscopes were too limited to definitely establish the functions of the minute forms or their relations to the higher orders The belief, however, was becoming more and more general that the minute forms had something to do with bodily ailments and fermentations, but without microscopical aid it could not be clearly demonstrated. As must be expected, some extravagant views were adopted, while others were close approximations to the truth. Boerhaave, in 1693, distinguished three kinds of fermentations, viz , alcoholic, acetous, and putrefactive. Linnæus stated that a certain number of diseases resulted from animated invisible particles dispersed through the air. Spallanzani, in 1769, started his series of experiments upon spontaneous generation and ste-

rilization, resulting in the present method of preserving foods. Opinions were very conflicting, and the truth, which may now be expressed by a line, required years of labor to ascertain, and really follows the improvement in the microscope. In 1837 Cagniard-Latour described yeast as a collection of globules which multiplied by budding. In 1838 Turpin described the yeast plant in beer, and named it *Torula cerevisiæ*. Many chemists were unwilling to admit the important part played by yeast in fermentations, and ascribed it to "catalysis," or action by presence. In 1843 the celebrated French chemist Dumas, from microscopical and chemical examinations, clearly explained the physiological function of the living ferment, yeast. The truth was now proven, but it made little progress until Louis Pasteur, some ten years later, took up the work of studying under the microscope the ferments of yeast, vinegar, and wine, demonstrating conclusively that a germ must be present to start fermentation or decomposition in fluids, that the definite knowledge he learned of the functions of the minute forms of life attracted attention.

Pasteur, by his systematic work with his microscope, tracing the life history of many ferments from the spore, ascertained the laws of growth, so he could induce fermentation or check it as desired. The ability to keep liquids for years when freed from germs, which under ordinary circumstances would ferment or decompose in a few hours, enabled Pasteur to confirm and clearly set forth the general principles of the germ theory of minute forms of life, in place of the theory of spontaneous generation. The theory so completed, revolutionizing current ideas, met with vigorous opposition, but the microscopical demonstration was so complete it has proven invulnerable, and upon it has been formed the important branch of science, bacteriology. We are too near to estimate the value of the demonstration. It will require time to show its full value, for its application is but really commenced.

Pasteur's work has been pre-eminently practical, and the results of his investigations at once applied to the French industries, in which interests they were undertaken. He saved the French silk industry from threatened destruction by investigating the parasitic diseases of the silkworm, and suggested a remedy. His investigations led to the antiseptic treatment in surgical operations which is now considered indispensable. His extensive

experiments to obtain vaccines, or attenuated virus for protective inoculations, have been very successful, especially when the difficulties of producing an attenuated virus are considered.

The process for obtaining the protective virus for rabies may be mentioned. He inoculates a morsel of the brain of a mad dog into the brain of a rabbit, which attenuates the virus sufficiently to act as a protective inoculation for dogs, or men bitten by dogs, suffering from rabies. At first the attenuated virus from the rabbit was also passed through the organism of the monkey before using. This feature has been discontinued. This was the first successful step towards checking rabies. Pasteur has a large institute in Paris for the treatment of rabies, and there is now in this city a branch institute under the charge of Dr. Paul Gibier, where about 160 persons have been successfully treated the past year.

Considering for a moment the higher orders of plant life, the microscope has shown conclusively that the functions of the fungi which we see upon them is to undo the structure which has been built up by the higher plants, returning the elements composing them to the air and soil. This is of itself a work of great economic value, and must be more generally understood to save our building timber and forests from the natural process of decay.

The rapid advancement of bacteriology in the last decade is largely due to the arduous labors of Koch, who, by extensive microscopical investigations, discovered the specific bacillus of several diseases, particularly of Asiatic cholera and tuberculosis. He originated a method of staining a specific bacillus so as to differentiate it from all others in enclosed tissue or other media, and found them when others not using as skilful methods failed. He originated a system of solid nutritive media for cultivating and isolating a specific bacillus, producing pure cultures. This has proven of the greatest value, for much has been learned as to the manner of growth and products secreted of each bacillus studied. With the pure cultures he carried out extensive inoculations on animals, and carefully noted the effects. The latter have been analyzed, resulting in his extensive experiments with his so-called lymph to check the bacillus of tuberculosis in the human system. It is this feature of Koch's great work which has made his name a household word to-day in all civilized countries.

Yesterday he gave to the world the formula for his great discovery, which, briefly stated, is a glycerin extract of a certain dilution from the ptomaïnes or the products of the bacillus itself.

The consensus of opinion from the tests is that it is a remedy of great value. Besides its direct benefits the indirect ones will be even greater, for the publicity given by the press to this and kindred discoveries is rapidly educating the people to the important rôle played by microbes in contagious diseases, and the necessity of efficient sanitary measures for our cities as a preventive. Check the causes instead of dealing with the dangerous effects, and have clean streets, wholesome water, and efficient sewerage. Any one or all of these, when not in proper condition, are efficient media for the growth of microbes detrimental to health, particularly in cities of warm climates. But few of our cities in warm climates have as wholesome water as is needed for domestic purposes, being so filled with germs as to be unsafe for many persons to drink without sterilization. The indifference of the people to these important matters is largely due to the fact that their nature and bearing are not understood. The reasons why the streets should be clean, the water wholesome, and that there should be efficient sewerage in our cities, are evident to health boards, but it needs enlightened public opinion to more thoroughly carry out the demonstrations of the microscope.

PROCEEDINGS.

Meeting of December 5th, 1890.

In the absence of the President and Vice-President, Mr. William Wales was elected chairman.

Twelve persons present.

The Corresponding Secretary exhibited the first and second numbers of the new publication, *Le Diatomiste*, edited by M. J. Tempère, Paris, and gave notice of the character of the publication.

OBJECTS EXHIBITED.

1. Longitudinal and transverse sections of an Actinia, *Metridium marginatum* Milne-Edwards, showing tentacles, mouth, œsophageal tube, and mesenteric folds : by L. Riederer.

2. Pipe-fish, *Syngnathus acus* L. Entire fish, young, stained: by L. RIEDERER.

3. Sagittal sections of the head of the same: by L. RIEDERER.

4. Type-slide of 50 recent and fossil Foraminifera, prepared by Edmund Wheeler: by H. W. CALEF.

The following all by ANTHONY WOODWARD:

5. Type-slide of 100 species of Foraminifera, from H M. S. "Challenger" Expedition, Torres Straits, 155 fathoms, prepared by Joseph Wright, Belfast, Ireland.

6. Section of *Eozoon Canadense*.

7. Section of fusulina limestone from Nevada. Also many specimens, such as *Planorbulina larvata*, *Calcarina Spengleri*, *Assilina*, *Numulites*, *Orbitoides Mantelli*, *Fusulina cylindrica*, Foraminifera of the U. S. coast, of Bermuda, of Singapore, and of the Vienna Basin, and others embracing forms extending from the carboniferous age to the present time.

A discussion on building-stone was participated in by Messrs. A. Woodward and M. M. Le Brun.

Mr. Riederer gave the following description of his exhibits: "The Actiniæ belong to the Cœlenterata, or zoophytes. They are cylindrical and radially symmetrical. The oral opening is used not only for the reception of the food, but also for the rejection of excreta. This opening is surrounded by tentacles—contractile tubes—bearing, especially near the ends, large numbers of 'nettle-cells'—cnidoblasts.

"The cavity of the body is divided by numerous vertical partitions—mesenteric folds—into a system of vertical pouches, which communicate with one another at the bottom of this gastric cavity. At the upper extremity the pouches are continuous with the canals leading into the hollow tentacles, since the edges of the mesenteries bounding them unite with the wall of the oral tube, which hangs from the mouth. The generative organs rise on the mesenteries as band-shaped or folded thickenings.

"The body of Actinia has no hard structure. By means of contractile muscles, causing inflow and outflow of water, large differences in size and shape are produced. The contractile foot allows departure from the place of attachment. Many Actiniæ reach a relatively large size and possess beautiful colors.

"The Pipe-fish, *Syngnathus acus*, belongs to the Teleostei, or bony fishes. It is the most common and widely propagated fish of its family. The body is cylindrical, laterally compressed, and covered with a mailed skin. The elongated, tubular snout has no teeth, and opens in front at the top. There are four tufts of gills on each side, and the gill-openings are narrow. The males have brood-pouches on the abdomen. The dorsal fin shows forty rays, but the pectoral and anal fins are small. The tail appears like a fan on a long handle at the end of the long body. Thus the propulsion of the fish is done mostly by the undulating movements of the dorsal fin. The Pipe-fish is found between sea-weeds at the bottom of shallow waters, and feeds on small crustaceæ and worms."

Meeting of December 19th, 1890.

The President, Mr. P. H. Dudley, in the chair.

Eighteen persons present.

The following Committee on Annual Reception was appointed by the chair: Messrs. Charles S. Shultz, George E. Ashby, and Anthony Woodward.

OBJECTS EXHIBITED.

1. A Fish-louse: by F. W. Leggett.
2. *Gomphonema herculeanum* from Dutchess County, N. Y.: by J. D. Hyatt.
3. The Polycistin, *Haliomma Humboldtii:* by Stephen Helm.
4. Polycistina from Barbadoes: by James Walker.
5. Foraminifera from Isle of Jersey, England: by James Walker.
6. Section of *Nummulina lævigata* from Bartom, England: by James Walker.
7. Foraminifera from Bermuda: by William G. De Witt.
8. *Orbiculina* from Bermuda: by William G. De Witt.

Mr. Stephen Helm, of 417 Putnam Avenue, Brooklyn, addressed the Society on "The Foraminifera." This address was illustrated by numerous beautiful and enlarged diagrams, especially prepared by Mr. Helm for the occasion.

On motion the thanks of the Society were tendered Mr. Helm for this address.

Dr. H. Hensoldt remarked upon the subject of the Foraminifera, reviewing the interesting geological side of the subject.

Mr. Hyatt said of his exhibit that it was collected on the 23d of November last, from a brook in Dutchess County, N. Y., where it suddenly appeared, and increased so rapidly as to cover the stones, etc., on the bed of the stream to the thickness of more than one-quarter of an inch. And, further, that the only published locality for this rare diatom is Lake Erie.

Meeting of January 2d, 1891.

The President, Mr. P. H. Dudley, in the chair.

Thirty-five persons present.

The Committee on Nominations of Officers, appointed at the meeting of November 21st, 1890, reported their nominations of the persons who were unanimously elected, as is stated below.

The President appointed as tellers of the election of officers the Rev. George C. F. Haas and Mr. Horace W. Calef.

Mr. Charles F. Cox read the following papers, as announced on the programme of the evening:

1. "On the Structure of the Pleurosigma Valve"; by T. F. Smith, Esq., F.R.M.S., of London, England. This paper, published in the present number of the Journal, p. 61, was illustrated by lantern projections of fifty excellent lantern slides, from original photomicrographs. and by numerous other mounted photomicrographs, by Mr. Smith.

2. "Diatom-Structure—The Interpretation of Microscopical Images"; by Jacob D. Cox, LL.D., F.R.M.S., of Cincinnati, Ohio

This second paper, published in the present number of the Journal, p. 73, was illustrated by one hundred photomicrographs, twelve of which were by the late Col. J. G. Woodward.

Mr. Charles F. Cox announced the donation to the Society by Mr. T. F. Smith of the fifty lantern slides just exhibited.

On motion it was resolved that the thanks of the Society be hereby tendered Mr. T. F. Smith for his interesting and valuable paper, "On the Structure of the Pleurosigma Valve," and for his

valuable donation of fifty photomicrographic lantern slides illustrating the same.

On motion it was also resolved that the thanks of the Society be hereby tendered Gen. Jacob D. Cox for his admirable paper on "Diatom-Structure—The Interpretation of Microscopical Images."

The President announced the closing of the polls, and declared the result of balloting to be the election of the following persons as officers of the Society for the present year :

President, P. H. Dudley.
Vice-President, J. D. Hyatt.
Recording Secretary, Bashford Dean.
Corresponding Secretary, J. L. Zabriskie.
Treasurer, Charles S. Shultz.
Librarian, Ludwig Riederer.
Curator, William Beutenmüller.
Auditors, { William E. Damon, F. W. Leggett, H. W. Calef.

Meeting of January 16th, 1891.

The President, Mr. P. H. Dudley, in the chair.

Twenty-five persons present.

The Treasurer, Mr. Charles S. Shultz, presented his annual report, which was accepted and adopted, and the summary of which is as follows :

Receipts, - - - - -	$530 08
Disbursements, - - - -	421 47
Balance, - - - -	$108 61

The Committee on Publications presented their annual report, which was accepted and adopted.

The Curator, Mr. William Beutenmüller, presented his annual report, stating that he was now cataloguing the slides in the cabinet of the Society, and also that the six revolving tables now in the Society's Rooms had been lately there deposited by some unknown parties.

On motion the thanks of the Society were tendered the donors of these elegant and useful tables.

The President made the following appointments:

Committee on Admissions: F. W. Devoe, Anthony Woodward, William E. Damon, George F. Kunz, and William Wales.

Committee on Publications: J. L. Zabriskie, William G. De Witt, Walter H. Mead, John L. Wall, and Charles F. Cox.

The President delivered his annual address, entitled "The Work of the Microscope," and published in this number of the JOURNAL, p. 87.

Mr. Stephen Helm, of 417 Putnam Avenue, Brooklyn, delivered the third of his series of addresses, entitled "The Rotifera." This address was illustrated by beautiful enlarged diagrams, and by living objects under microscopes.

OBJECTS EXHIBITED.

1. *Stephanoceros Eichhornii:* by STEPHEN HELM.

2. *Floscularia ornata:* by STEPHEN HELM.

3. Longitudinal section of head of embryo of Garter Snake, *Eutania sirtalis* L.: by L RIEDERER.

4. Transverse section through nose of the same: by L. RIEDERER.

5. Transverse section through eye of the same: by L. RIEDERER.

In discussion of the address, Mr. C. Van Brunt stated, as the result of his observations on the desiccation of Rotifera, that when they are dried on the surface of clean glass they are dead and incapable of resuscitation; but if dried among fragments of dirt or vegetable matter they may be revived. He had some pond mud, which had been kept dry, wrapped in paper, for the space of five years. When portions of this were moistened with water the contained Rotifera would revive in two hours' time.

Mr. Riederer remarked on his exhibits: "This harmless snake, *Eutania sirtalis*, belongs to the family Colubridæ. It has a moderately broad and distinct head, covered with scutes. The dentition is complete. It shows a remarkable variability, which has given opportunity to the formation of quite a number of sub-species.

"In the following remarks I refer only to such points as can be seen in the transverse or the sagittal sections of the head of the embryo here exhibited. Commencing with the lower jaw,

we see the cartilaginous structure of the bones, as yet unossified, bundles of muscles, and blood vessels. The forked, horny tongue is enclosed in a sheath, from which it can be protruded through an indentation of the mouth, even when the mouth is closed. Above the tongue is the larynx. This is placed extraordinarily far forward, and can be projected into the mouth during the long and difficult act of swallowing. The adjoining trachea shows cartilaginous rings. While all reptiles breathe only by lungs, the embryonic stage of the object still shows the presence of gills. The gullet has a thin, extensible wall. The nasal apertures are placed near the apex of the snout. The olfactory organ has a second groove, with a large surface of mucous membrane, supported by cartilaginous whorls. The olfactory nerve rises at the end of the olfactory lobe, and is spread out like a cup around a cartilaginous papilla. The eyes are without lids, but are protected by a transparent capsule, formed by the skin, filled with lachrymal fluid, and transparent in front of the pupil and cornea. The eyes show all the constituents of a highly developed vertebrate: cornea, crystalline lens, anterior and posterior chamber, iris with pupil, retina with its different layers, choroid with pigment, and optic nerve. The brain, enclosed in the cartilaginous capsula, shows differentiation in layers and structure."

PUBLICATIONS RECEIVED.

The Microscope: Vol. X., No. 11--Vol. XI., No. 1 (November, 1890—January, 1891).

Bulletin of the Torrey Botanical Club: Vol. XVII., No. 12—Vol. XVIII., No. 2 (December, 1890—February, 1891).

Natural Science Association of Staten Island: Proceedings; Meetings of December, 1890, and January, 1891.

Journal of Mycology: Vol. VI., No. 3 (January, 1891).

The Botanical Gazette: Vol. XV., No. 12—Vol. XVI., No. 2 (December, 1890—February, 1891).

Insect Life: Vol. III., Nos. 4, 5 (November, 1890, January, 1891).

Entomologica Americana: Vol. VII., No. 12 (December, 1890).

Psyche: Nos. 175—178 (November, 1890—February, 1891).

Anthony's Photographic Bulletin: Vol. XXI., No. 23—Vol. XXII., No. 3 (December 13, 1890—February 14, 1891).

Academy of Natural Sciences of Philadelphia: Proceedings; 1890, Part 2.

Connecticut Academy of Arts and Sciences: Transactions; Vol. VIII., Part 1 (1890).

New York Academy of Sciences: Transactions; Vol. X., No. 1 (October, 1890).

School of Mines Quarterly: Vol. XII., No. 1 (November, 1890).

American Museum of Natural History: Bulletin; Vol. III., No. 1 (December, 1890).

Rochester Academy of Science: Proceedings; Vol. I., No. 1.

Cincinnati Society of Natural History: Journal; Vol. XIII., No. 4 (January, 1891).

Newport Natural History Society: Proceedings; Part 7 (1890).

California Academy of Sciences: Occasional Papers; Parts 1, 2 (1890).

Saint Louis Academy of Science: Constitution and List of Members (1890).

Colorado Scientific Society: Proceedings; Vol. III., Part 2 (1889).

Meriden Scientific Association: Transactions; Vol. IV. (1890).

Bulletin of the Essex Institute: Vol. XXII., Nos. 4—6 (April—June, 1890).

West American Scientist: Vol. VII., No. 55 (December, 1890).

Vassar Brothers Institute: Transactions; Vol. V., Nos. 1, 2 (1890).

United States Geological Survey: Ninth Annual Report (1888).

Cornell University College of Agriculture: Bulletins Nos. 23—25; Annual Report (1890).

Kansas State Agricultural College: Bulletin No. 12 (August, 1890).

Agricultural Experiment Station of Alabama: Bulletin No. 20 (November, 1890).

Michigan Agricultural Experiment Station: Bulletins Nos. 67—69 (October, November, 1890).

United States Department of Agriculture: Farmer's Bulletin 1890).

Boston Society of Natural History: Insecta; By Alpheus Hyatt and J. M. Arms.

Le Diatomiste: Vol. I., No. 3 (December, 1890).

Johns Hopkins University Circulars: Vol. X., Nos. 84, 85 (December, 1890, February, 1891).

Electrical Engineer: Vol. X., No. 133—Vol. XI., No. 146 (November 19, 1890—February 18, 1891).

Mining and Scientific Review: Vol. XXV., No. 22—Vol. XXVI., No. 8 (November 27, 1890—February 19, 1891).

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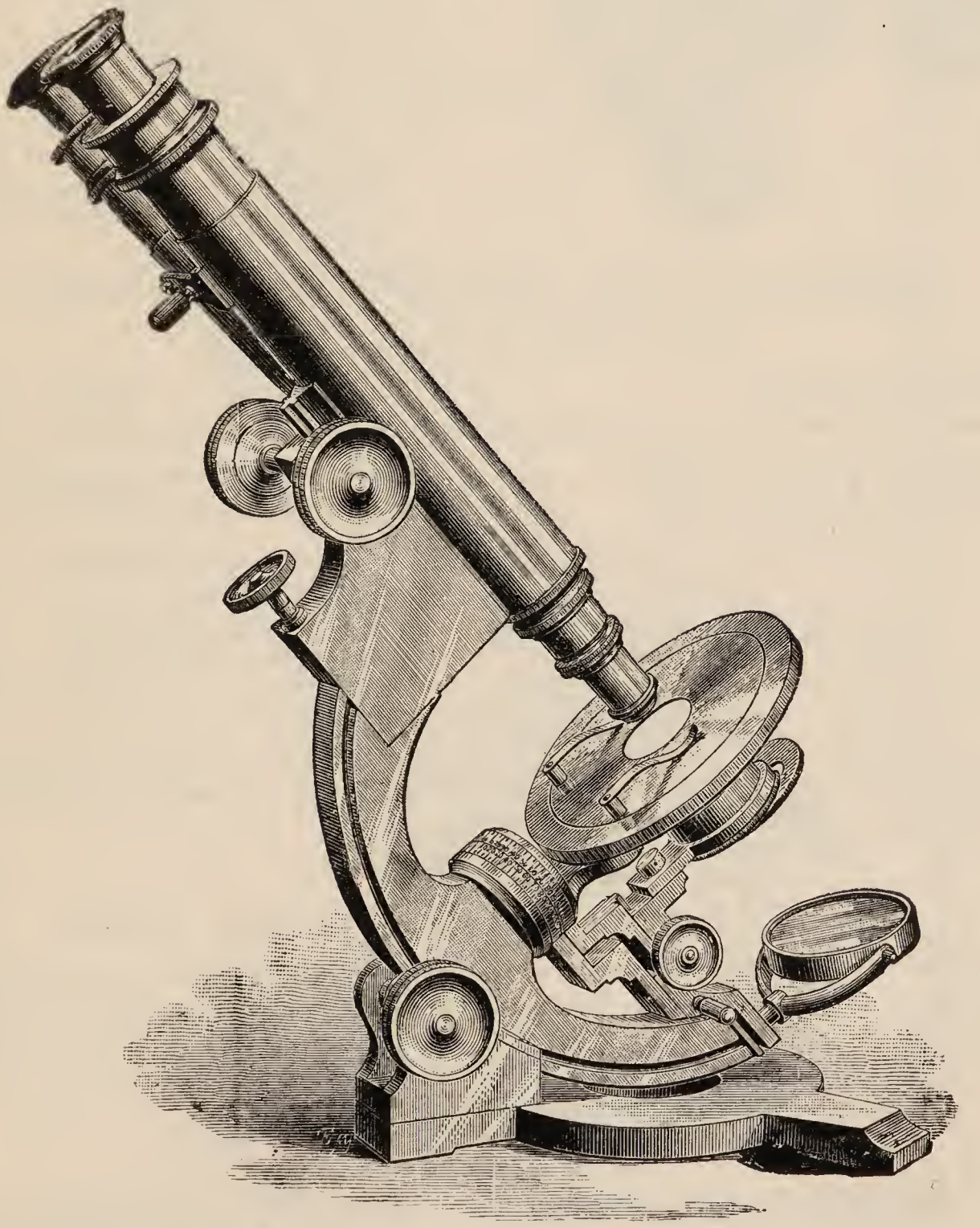

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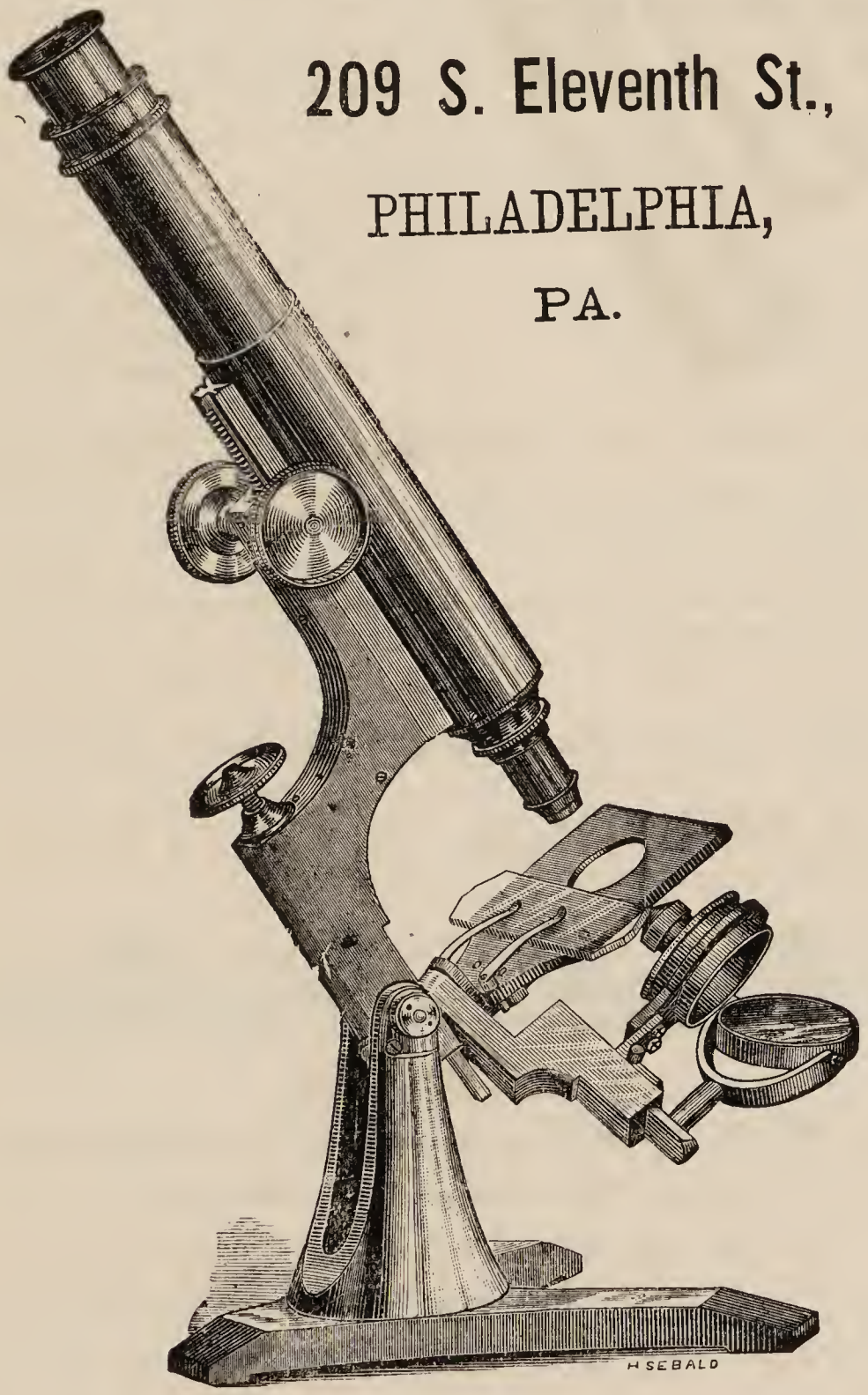

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